In Class Activity Plan
Week Four: Developing 2D Motion

45 min **Video Analysis of 1-d Motion (Word, Pdf)**
PURPOSE: Confirm that acceleration due to gravity is 9.8 m/s^2 and always points straight down.

Logistic Notes:
For detailed instruction see Instructor Notes for 1d Motion analysis (Word, Pdf)

- Have students load the file *KramerToss1.cmbl* (**right click, save as**) that includes the video file and the position graph in Logger Pro. (*Note: You also need the mov1.m4v video file to properly run this file.*)
- The students will have to set the scale on the video in order to get accurate values for the acceleration due to gravity.
  - Click on the little meter stick symbol next to the video
  - Draw a line on top of the meter stick
  - A box will open that will ask you what is your unit of measurement for the scale.
- They will also need to set the origin (it doesn't really matter where they set it)
- They will use the cross-hair icon to click on the ball in each frame of the video. This will create a position-time graph.
- Once they understand the position-time graph, you will want them to look at the velocity time graph, and use the linear fit to the find the slope.
- ***NOTE:*** *To get an acceleration value very close to 9.8 you need to set the scale such that the meter stick is .9m not 1m.*

10 min **Whiteboard – Video Analysis of 1-d motion**
PURPOSE: Summarize lab activity
- What rules can you make?
- What questions do you still have?

20 min **Board Meeting**
PURPOSE: Confirm that basic constant a model works in free fall; build consensus about value of a_g
- The v-t graph is a straight, negatively sloped line that crosses the x-axis
- The value of the constant acceleration is approximately 9.8
- 9.8 m/s^2 is the value of the acceleration due to gravity

15 min **Instructor led discussion**
PURPOSE: Elicit ideas about models in 1-d vs. 2-d.

"What do you think would change about our constant acceleration model if the motion was in 2 dimensions?"
Note: You might have to discuss what dimension means.

- How do you think the model changes? *(e.g. now there is more than one direction so we need vectors)*
- What stays the same? *(e.g. the tools we have such as graphs and motion maps)*

15 min **Whiteboard - Make a 2-d Motion Map**

PURPOSE: Introduce key difference between 1-d and 2-d motion using motion maps.
Throw a ball (or keys or some small object) so that it undergoes projectile motion.

- Ask students to make a motion map of the ball on whiteboards
- As they work, go around and check for:
  - Velocity vectors must be straight lines
  - Make sure at least one group has a velocity vector completely horizontal at the top point

15 min **Board Meeting**

PURPOSE: Build consensus about differences between models in 1-d vs. 2-d.

- What do we notice about the velocity vectors on the 2d motion maps?
  - They must still be straight lines
  - They point at an angle
  - They change lengths
  - The topmost point isn't 0 like in 1d motion, but is completely horizontal
- What do we notice about position?
  - The dots are in an arc not a line
  - We need a way of finding the displacement

30 min **Vector analysis (Word, Pdf) & Introduction to two dimensional motion (Word, Pdf)**

PURPOSE: Remind students how to add vectors; introduce 'whole vector' tool for analysis of 2-d motion. *(See* D. Wheeler and N. Charoenkul, "Whole vectors," Phys. Teach. **36**, 274 (1998) *for more information)*

Logistic Notes:

- We suggest handing out the two documents at the same time, but the students need to complete "Vector Analysis" prior to "Introduction to Two Dimensional Motion"
- We expect that Q7-8 will lead to a instructor led discussion of how we need to be careful of displacement in two-dimensions, which leads to the PowerPoint presentation in the next activity

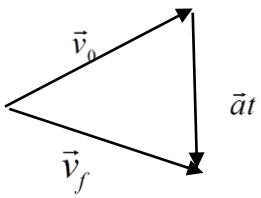
30 min **Instructor led discussion - 2d Motion Over Time (Power Point, Pdf)**

PURPOSE: Develop the whole vector approach to the $d = v_o t + \frac{1}{2} at^2$ equation.

Logistic Notes:

- In slides 2 – 7 the focus is on the path of the ball. Make sure the students agree the dots represent the position for a point in time.
- Slide 8 shows the initial velocity vector scaled by 1 sec, the acceleration vector scaled by $1/2t^2$, and the addition of the two leading to the position of the ball at t=1sec.
- Slides 9 – 12 continue scaling the initial velocity vector and the acceleration vector until the ball reaches its final position.
- Slide 13 shows all of the vectors scaled from the previous few slides. Important things for discussion:
  - What does the red line represent? The blue line?
  - Are the lines changing direction?
  - How are they getting longer? What is changing here?
- Slide 14 returns to the original question of how to find displacement for any point in time. Remind the students that displacement is defined as the change in position over time. So that the green arrow represents the displacement from t=0 sec to t=1sec.
- Slides 14 – 18 step through the displacements between the ball's initial position and consecutive location for the ball over time. At slide 18 point out:
  - This triangle looks exactly like the one from the Introduction to Two Dimensional Motion worksheet.
  - What about the other triangles previous to the final one? Could we use the same vector equation to find the displacement for any time?
- Once the displacement discussion is completed, ask if the same thing could be done for velocity? What would the equation and vector triangle look like? (See below)

$$\vec{v}_f = \vec{v}_0 + \vec{a}t$$



15 min **Whiteboard – First problem on Two Dimensional Motion Problems (Word, Pdf)**

PURPOSE: First practice at using 'whole vector' approach to kinematics

Do one problem together as a class

Have each group do this problem on the whiteboard and this discuss before moving on to new problems.

15 min **Board Meeting**
PURPOSE: Build consensus on using 'whole vector' approach to solving 2-d problems
Video Examples: (Problem1, Problem3, Problem3)

60 min **Two Dimensional Problems (Word, Pdf)**
PURPOSE: Gain further practice working on using whole vector approach to kinematics; see a variety of problems.
Give plenty of time for all groups to work through the majority of these problems. This is a new way of thinking and requires practice.

Logistic Notes:
- You will probably have to remind them of a lot of geometry/trig stuff here
  - Law of sines
  - Law of cosines
  - Basic SOH CAH TOA

Homework: 2D Motion Ranking Taks (Word, Pdf)